Reducing metal consumption

Practical suggestions for the raw materials transition

PowerShift
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Reducing metal consumption: practical suggestions for the raw materials transition

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List of abbreviations

BGR	Federal Institute for Geosciences and Natural Resources
BMDV	Federal Ministry for Digital and Transport
BMG	Federal Ministry of Health
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection
BMWK	Federal Ministry for Economic Affairs and Climate Action
BMWSB	Federal Ministry of Housing, Urban Development, and Building
CRMA	Critical Raw Materials Act
DERA	German Raw Materials Agency
DMC	Domestic material consumption
SFD	Single-family dwelling
IEA	International Energy Agency
ICT	Information and communication technology
JRC	Joint Research Centre of the European Commission
MFD	Multiple-family dwelling
RMC	Raw material consumption
RME	Raw material equivalents
UBA	German Environment Agency
UNEP	UN Environment Programme
WTG	Wind turbine generator

Introduction

Protests after the dam failure at the iron ore mine near Brumadinho in Brazil, during which 272 people died in 2019.
Photo: Rodrigo S Coelho, Shutterstock

In recent years, production lines in Germany have repeatedly come to a standstill. Supply chains have been disrupted by wars, pandemics, and floods. After decades of secure supplies of raw materials and intermediate products, dependencies on individual suppliers have become apparent. Shifts in geopolitical power and production, an increase in climate events, and metal supply shortages may lead to more fragile supply chains and further production disruptions in the future. Both Germany and the EU are responding with various measures to maintain security of supply for their industries. All of them share the goal of securing the flow of raw materials to Germany and Europe, while largely ignoring globally unjust and ecologically disastrous consumption.

Nonetheless, EU Commission President Ursula von der Leyen announced in her State of the Union address in September 2022 that access to raw materials is crucial *'for the success of our transformation towards a sustainable and digital economy'*.[1] In her speech, she promised legislation to secure the supply of raw materials. The political agreement between the EU Commission, EU Parliament, and member states was reached just over a year later – in December 2023, the *Critical Raw Materials Act* (CRMA) was confirmed by the Parliament. EU Internal Market Commissioner Thierry Breton was delighted: *'The pace of the negotiations and the scale of the ambitions show that raw materials have become indispensable for Europe's economic security and resilience. [...] With this new law, we are increasing our capacities for the extraction, processing, refining, and recycling of raw materials in Europe while complying with the highest environmental and social standards.'*[2]

At the same time, protests against mining and the destruction of the environment and livelihoods continue in resource-rich regions. Many protesters risk their lives.[3] German companies are repeatedly linked to human rights abuses and environmental destruction in international mining: as recently as January 2024, Climate Rights International highlighted the environmental and social impacts of nickel mining in Indonesia (with reference to Volkswagen),[4] and in November 2023, media outlets NDR, WDR, and SZ reported on labour rights violations and arsenic poisoning in cobalt mining in Morocco (with reference to BMW).[5] 25 January 2024 marked the fifth anniversary of the fatal rupture of the iron ore mine tailings dam at Brumadinho in Brazil, which claimed the lives of 272 people and caused significant environmental damage (with reference to TÜV Süd).[6] Human rights abuses in bauxite mining in Guinea have been repeatedly denounced by FIAN and PowerShift since 2019 (with reference to German car manufacturers and banks).[7] In 2016, Amnesty International documented child labour and labour rights violations in the cobalt sector in the DR Congo in a study (with reference to various German car manufacturers), and in August 2012, 34 striking platinum miners in South Africa, working under life-threatening conditions and with poor pay, were shot dead (with reference to BASF).[8]

In addition to poor working conditions, lack of compensation, and violent repression of resistance and strikes, social protests are often sparked by the environmental risks of mining and processing – including high CO_2 emissions from processing primary metals,[9] deforestation,[10] consumption of drinking water,[11] and environmental damage caused by the breaching of dams. As a result, an international team of scientists has concluded that *'peak mining'*, the point at which the largest amount of ore is extracted, must be reached by 2030 at the latest in order to meet climate targets.[12] Despite these imperatives, many expect future demand for metals to increase. In particular, future technologies for digitisation and decarbonisation will require huge amounts of metals.[13] This growth in some sectors, coupled with declining ore reserves in some cases, is leading to early warnings of possible bottlenecks and shortages (e.g. for copper).[14]

The energy transition, the shift away from fossil fuels, and the global expansion of renewable energies are inevitable. At the same time, our societies will continue to need metallic raw materials in the future. It is therefore necessary to analyse the consumption of these raw materials in more detail in order to identify potential areas where metal consumption can be reduced. In collaboration with the ifeu Institute, a study was therefore carried out to analyse the potential for reducing the use of various metals, which forms the basis of this publication.[15] The study focuses on copper, aluminium, iron, steel, and nickel, as these base metals account for 94 percent of the total consumption of metallic raw materials in Germany.[16] Copper, aluminium, and nickel are classified by the EU as both Critical and Strategic Raw Materials.[17] Their classification as Critical and Strategic means that projects for the extraction of these raw materials will receive special political support in the future. This includes accelerated authorisation procedures and, in certain circumstances, financial support for mining projects.

In March 2024, the International Resource Panel of the United Nations Environment Programme (UNEP) published its Global Resources Outlook for 2024.[18] It shows that resource consumption has tripled since 1970 and could increase by a further 60 percent by 2060. The UNEP International Resource Panel therefore calls on policymakers to step up efforts to improve resource efficiency and reduce consumption.

The underlying study focused in particular on measures that are within the realm of political implementation. But even these debates on *'soft measures'* to reduce emissions are still in their infancy. The need for action is also recognised by the EU and the German government: for example, the EU Parliament recently asked the EU Commission to calculate raw material reduction potentials in 2021,[19] the German coalition government has included the goal of reducing primary raw material consumption in 2021 in the German coalition agreement,[i] and even the extremely industry-friendly CRMA recognises the need for *'demand moderation'*.[20]

This publication has been produced with the aim of stimulating policy action for the sustainable use of metallic raw materials and improving the research and data base. The necessary changes for a raw materials transition can still be introduced in a planned manner (*'by design'*) rather than by necessity *('by disaster'*).[21] The implementation of reduction measures is a matter of great urgency in the context of global and social justice, environmental and climate protection, and with regard to the future supply of Germany and the EU.

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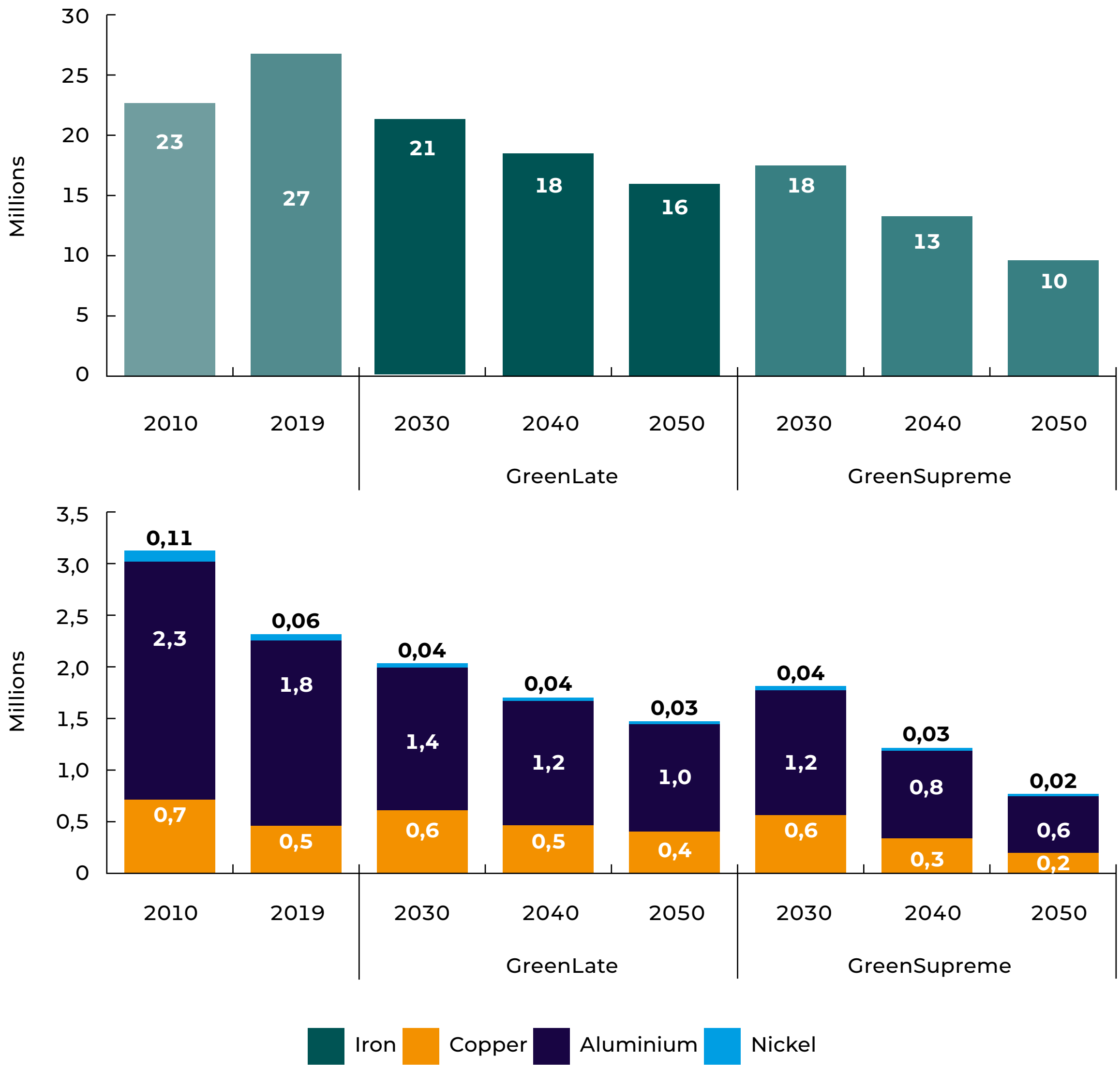
i *'We are committed to reducing the use of primary raw materials and closing material cycles.'* (SPD et al., 2021, p. 33)

Current and future use of the base metals analysed

Figure 1 – Primary metal consumption (last domestic use) of iron (top), copper, aluminium, and nickel (bottom) in Germany according to the RESCUE scenarios in million tonnes of metal content Source: Own figure based on Dittrich et al., 2024



Although mining has a long history in Germany, the country no longer has any significant mining operations. Almost all the ores processed here have to be imported. In 2022, 79.2 million tonnes of metals worth €104.2 billion were imported, of which only 7.9 million tonnes were recycled raw materials.[22] Well over 60 percent of this came from outside the EU,[23] but only a fifth of the imported metals are used for domestic consumption, with the majority being processed and exported. This type of metal throughput is therefore not reflected in some of the relevant consumption-related indicators for measuring material flows, such as the RMC or DMC.[ii] The use and consumption of metals in Germany has increased significantly in recent years. In total, around 168 million tonnes of primary metal raw materials were consumed in 2019.[24]

Just over half of final demand for metals is generated by households (54 percent), with the other half coming from investment in infrastructure, buildings, and government

ii RMC (raw material consumption): Measures the material footprint of domestic consumption, including the raw materials used to produce goods.
DMC (domestic material consumption): Measures only domestic material consumption, not indirect raw material flows along value chains.

Although there is no significant iron ore mining, Germany is the largest steel producer in the EU.
Photo: maki_shmaki, iStock

spending. Metals are used in all areas of household consumption – a total of around 76 million tonnes of raw material equivalents (RME)[iii]. In Germany, one third of this total is dedicated to the transport needs of private households. A further 19 million tonnes of RME are supplied to the housing sector each year, representing a quarter of the total metal demand for private household consumption. These two sectors therefore account for more than half of all metals used by private households in Germany.

Despite all the environmental and social risks associated with the extraction and processing of metallic raw materials, humanity will continue to depend on them. Since there are political, technological, and physical limits to their recycling, future reliance on mining cannot be completely avoided. However, the level of future demand is a highly politicised issue. Almost all of the frequently cited studies – by the International Energy Agency (IEA), the World Bank, the Fraunhofer Institute, the German Environment Agency (UBA), and the study by the University of Leuven for the European mining association Eurometaux – anticipate increased demand in future or decarbonisation technologies. There is little analysis of abatement potential outside these scenarios. Accordingly, additional demand is expected, in particular for future technologies that are not yet widely used today. In these scenarios, iron (or steel), copper, aluminium, and nickel play a crucial role in achieving greenhouse gas neutrality. However, of the studies mentioned, only the RESCUE study by the UBA[25] calculates the reduction potential of metallic raw materials and concludes that the demand for iron, copper, aluminium, and nickel will (have to) decrease in various scenarios towards resource-efficient greenhouse gas neutrality in Germany by 2050 (Figure 1).

Iron and steel

German consumption of iron was just under 50 million tonnes of RME in 2019. Iron and steel products are mainly used in infrastructure for building houses, bridges, and railways, as well as in vehicles, trains, and ships. In Germany, a comparatively high share goes to the automotive industry (Figure 2). Germany is the EU's largest steel producer and ranks eighth in the world. However, only 0.5 million tonnes of iron ore are mined in Germany each year.[26] As a result, Germany is heavily dependent on iron imports, which amounted to around 170 million tonnes of RME in 2019.

Based on the current amount of steel scrap used to produce crude steel in Germany, the recycling input rate is 45.8 percent. For the EU, the rate is even higher at 56 percent.[27]

iii To calculate raw material consumption (RMC), traded goods are converted into raw material equivalents.

Figure 2 – Use of steel in Germany and the EU in 2020
Source: Own figure based on Dittrich et al., 2024

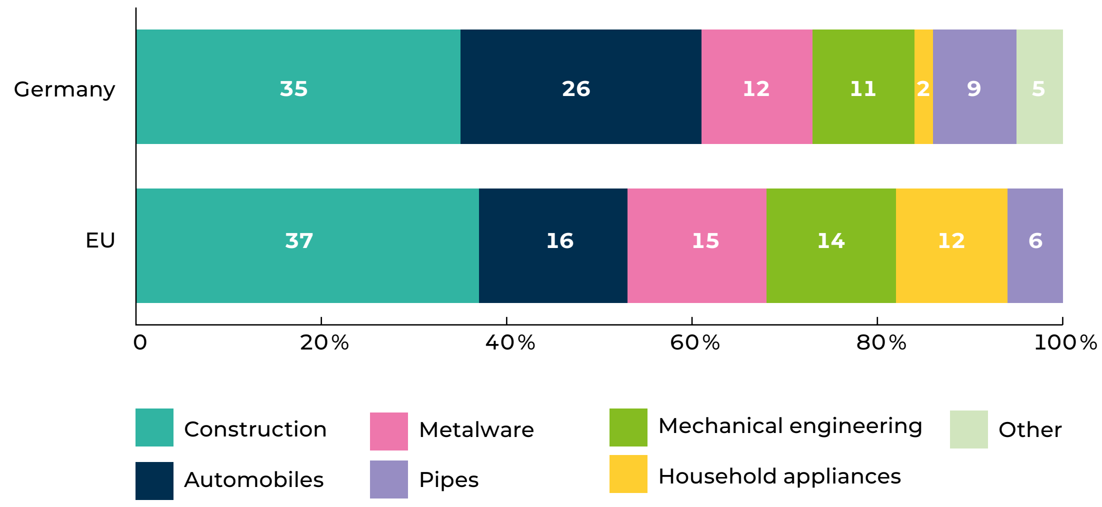
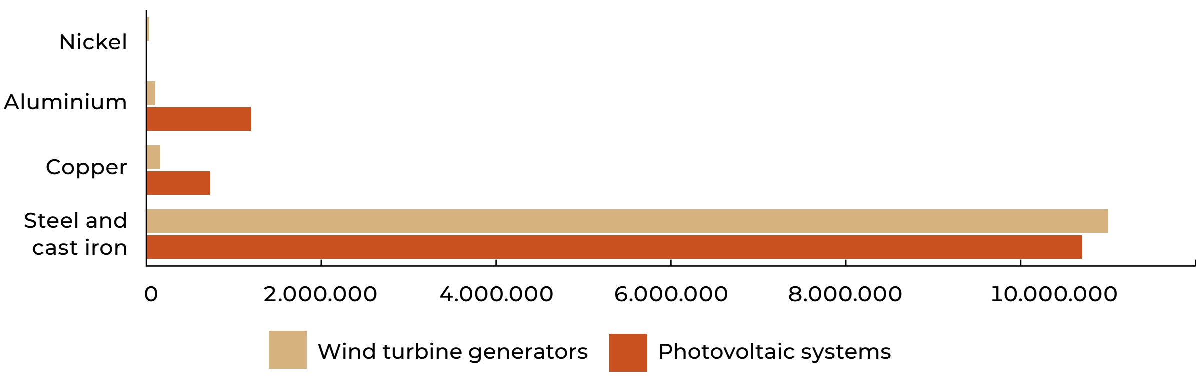


Figure 3 – Cumulative raw material requirements for the required net expansion of 82 GW of wind power capacity and 161 GW of solar power capacity in Germany by 2030 in tonnes
Source: Own figure based on DERA, 2022



Future use of iron and steel

According to the World Economic Forum, global demand for steel is expected to increase by 30 percent by 2050.[28] In a study for the German Raw Materials Agency (DERA), the Fraunhofer Institute analysed future changes in demand for selected future technologies[iv] on a global scale up to 2040: in line with an ambitious sustainable development, wind turbine generators (WTGs) are particularly important for the increasing demand for iron and steel.[29] In 2020, however, the global expansion of wind turbines accounts for only 0.6 percent of global steel demand and 1.6 percent of global cast iron demand.[30] DERA assumes a steel content of 30 to 35 percent in WTGs, which could result in an additional demand of around 18.7 million tonnes of steel and three million tonnes of iron for wind turbines alone by 2040.[31] To meet a large part of Germany's electricity demand from renewable energy sources, around two million tonnes of steel will be needed every year until 2030, with 950,000 tonnes for wind turbines and 1.07 million tonnes for PV systems (Figure 3). Other future technologies that will increasingly require iron and steel include superalloys and seawater desalination plants.[32]

Although the raw material requirements for batteries for mobility and energy storage are calculated,[33] car bodies and other car parts made of iron or steel are rarely included. The future needs of the construction sector are also generally poorly represented. There is also no equivalent value for fossil energy production to categorise future consumption in WTGs. It is worth noting that the iron consumption of coal-fired power plants is similar to that of WTGs and significantly higher than that of solar power installations.[34]

iv This includes: lightweight construction technologies, electric motors, autonomous driving, high-capacity storage, quantum computing, industrial robotics, fuel cells, carbon capture and storage (CCS) technologies, wind turbines, high-capacity permanent magnets, synthetic fuels, seawater desalination, power grid expansion, fibre optic cables, data centres, etc.

The automotive industry accounts for a high share of German raw material consumption of iron and aluminium. Photo: Traimak_Ivan, iStock

Aluminium

In 2019, German aluminium consumption amounted to just under ten million tonnes of RME.[35] The light metal, which is mainly extracted from the ore bauxite, is widely used in industry where weight savings are important and high strength and durability are required at the same time. In alloys, it has a very wide range of applications.[36] Almost half of the aluminium in Germany is used in the automotive and transport sectors (Figure 4). Aluminium is also important in the construction industry, for example in façades, roof and wall systems, windows, and doors. Aluminium also plays a key role in applications in the electrical and consumer goods industry, in mechanical engineering, and in the packaging industry.[37]

There is no bauxite mining in Germany, so all bauxite has to be imported. More than 90 percent of bauxite for the German market comes from Guinea.[38] However, Germany has a large secondary aluminium processing industry: in addition to 340,000 tonnes of primary aluminium, around three million tonnes of recycled aluminium were produced in 2022.[39]

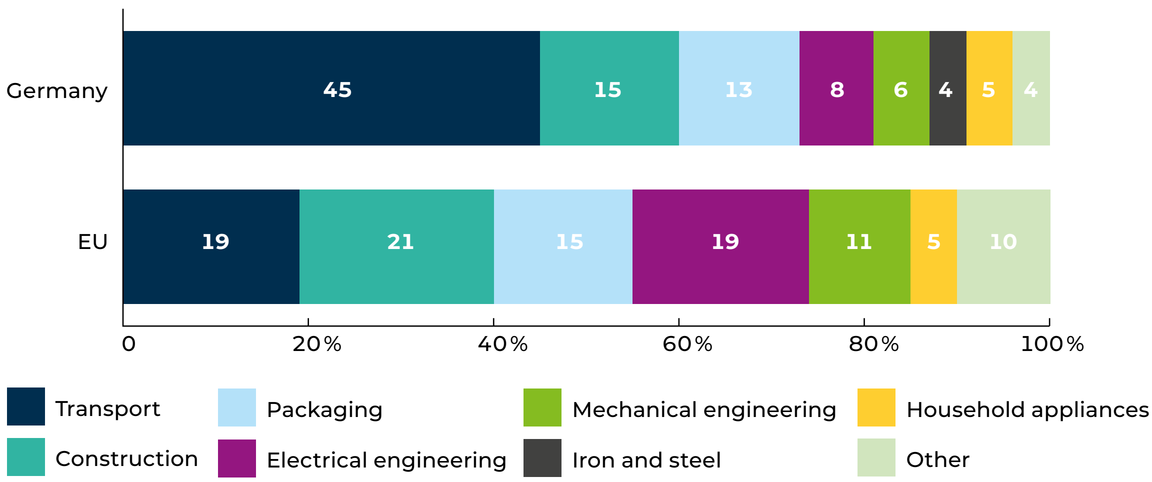
Future use of aluminium

As with iron, aluminium is needed for the expansion of wind turbines. Demand is expected to rise sharply in the coming years due to the ambitious expansion targets for renewable energy technologies. A study carried out by the Fraunhofer Institute on behalf of DERA predicts that global demand for aluminium for wind turbines will almost triple by 2040. However, high demand is also expected for water electrolysers and for use in stationary solid oxide fuel cells (SOFCs). Overall, global demand for aluminium will increase by more than three and a half times by 2040 as a result of the future technologies studied.[40] In Germany alone, according to a study by DERA, 10,000 tonnes of aluminium will be needed annually for the construction of wind turbines and 120,000 tonnes for the construction of PV systems in order to meet the German government's target of meeting 80 percent of electricity demand from renewable sources by 2030 (Figure 3).

According to the forecast of material demand for strategic technologies and sectors in the EU by the European Commission's Joint Research Centre (JRC), aluminium will be used in all 15 strategic technologies examined, with EU demand for these technologies expected to be between 882,000 and 1,375,000 tonnes in 2030 and between 1,334,000 and 2,064,000 tonnes in 2050.[41]

Figure 4 – Use of aluminium in Germany and the EU in 2019/2020

Source: Own figure based on Dittrich et al., 2024



In a study for International Aluminium, the total annual demand for aluminium in Europe alone is expected to increase by 4.8 million tonnes by 2030. Global demand will therefore rise from 86 million tonnes in 2020 to around 120 million tonnes in 2030. The largest growth sector will be automotive and transport, followed by electrical and construction. In Europe, the transport sector alone will require an additional 2.3 million tonnes of aluminium by 2030.[42] The main driver is the electrification of vehicles, which rely on lightweight materials to compensate for the heavy weight of their batteries.[43] In addition, around 19 percent of electric car batteries are made from aluminium.[44]

The automotive sector is also generally absent from studies on the future use of aluminium. Some studies mention batteries for mobility and energy storage, which account for up to around 50 percent of material consumption, but car bodies and other aluminium parts are rarely calculated.[45] Aluminium consumption in grams per megawatt hour is also higher in coal-fired power plants than in wind turbines.[46]

Copper

Around 44 million tonnes of RME copper were consumed in Germany in 2019.[47] Germany has a significant copper industry and the third largest copper demand in the world after China and the US. However, Germany has no copper mines of its own and relies entirely on imports, making it currently the fourth largest importer of copper in the world.[48] Copper is used, among other things, in the generation and transmission of electricity.[49] In Germany, more than half of copper (57 percent) is used in electrical appliances and installations, although nine percent of copper is also used in the automotive sector (Figure 5).

Increasing quantities of iron and steel, aluminium, copper and nickel are expected in the future for the expansion of wind energy. Photo: Thomas Reaubourg, Unsplash

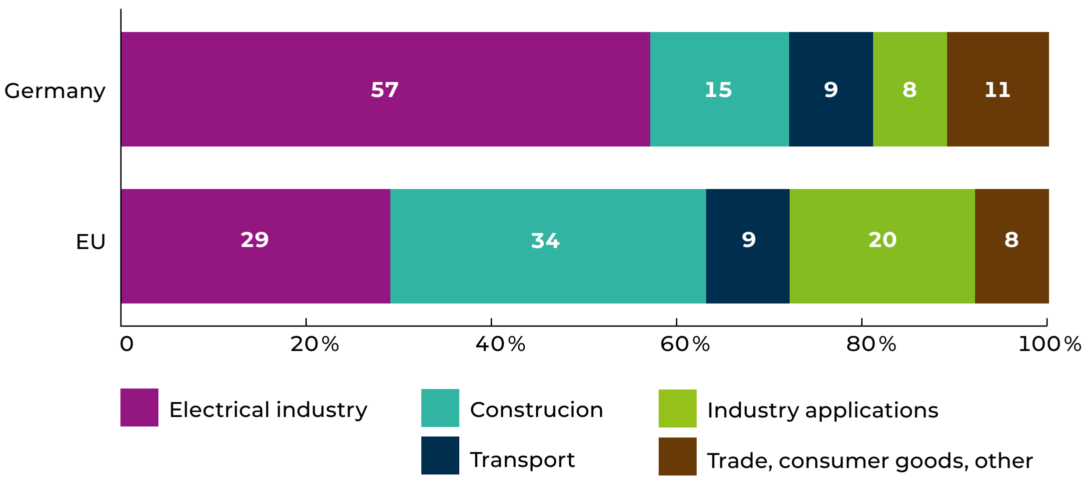
Due to the fact that secondary copper does not suffer any quality losses and raw material prices are high, copper recycling has long been of great importance.[50] In 2022, around 40 percent of the 609 million tonnes of refined copper produced in Germany were secondary copper.[51]

Future use of copper

Copper is considered a key metal in the energy and mobility transition. Copper is also seen as a Strategic Raw Material for the future due to its additional importance in the digital and green transformation, as well as in European space and defence.[52] It is particularly

Figure 5 – Use of copper in Germany and the EU in 2019/2020

Source: Own figure based on Dittrich et al., 2024



Opencast copper mining in Peru: Germany obtains almost 60 per cent of its imported copper ore from Peru, Chile and Brazil. Photo: tifonimages, iStock

important for the transformation of energy systems to achieve a significant reduction in greenhouse gas emissions.[53]

Copper is already required in very large quantities for the electrification of strategic technologies and is difficult to substitute. Although the EU's copper supply is highly diversified, the European Commission included copper in its list of Strategic Raw Materials for 2023.[54] For ambitious sustainable development, the Fraunhofer Institute estimates a significant increase in global copper demand by 2040 for selected future technologies alone.[v] Electric traction motors for motor vehicles, solid-state battery cells in e-mobility applications and water electrolysers will see particularly strong growth in global copper demand.[55] In general, copper demand is increasing due to the growing shift to electric vehicles, as they contain on average around 53 kilograms of copper, compared to only around 22 kilograms in conventional internal combustion engines.[56]

High demand is also expected for wind turbines.[57] In order to convert the German electricity supply to 80 percent renewable energies by 2030, 16,000 tonnes of copper will be needed annually for wind turbines alone and 73,000 tonnes for the expansion of PV systems (Figure 3).

In 2018, almost four million tonnes of copper were needed to expand electricity grids. In the case of ambitious sustainable development, as calculated by the Fraunhofer Institute for DERA, consumption would hardly change at all by 2040 and would be around 3.8 million tonnes. However, the Fraunhofer Institute also calculates a non-sustainable, fossil-fuelled scenario. In this scenario, demand for copper is forecast to increase dramatically: at 9.19 million tonnes, global demand for the future technologies examined would be more than double that of 2018, due in particular to a significant expansion of electricity grids. Accordingly, 8.21 million tonnes would be consumed in this sector in 2040.[58] In this case, a slower expansion of renewables would result in even higher copper demand.

Copper is a relevant raw material for 14 of the 15 strategic technologies in the EU whose future material consumption has been analysed by the JRC. EU-wide copper demand for these technologies is expected to be between 434,000 and 802,000 tonnes in 2030 and between 690,000 and 1.3 million tonnes in 2050. Based on the 127,000 tonnes of copper used in strategic technologies in 2020, this represents a fourfold increase in demand by 2030. Accordingly, copper is generally important for renewable energies,[vi] which will use about half of the copper (217,000 to 496,800 tonnes) in 2030. Heat pumps in particular will account for a large share (154,000 to 369,000 tonnes in 2030). Around a tenth of copper will also be used in the production of traction motors in 2030 (44,800 to 62,900 tonnes).[59]

Nickel

Around 3.2 million tonnes of RME nickel were consumed in Germany in 2019.[60] There are no nickel mines in Germany, but at EU level, nickel mining has been expanding continuously over the last decade.[61] Within the EU, 39 percent comes from Finland, 24 percent from Canada, 19 percent from Greece, eight percent from South Africa, and four percent from the USA.[62]

Nickel has been used in commercial batteries for a long time. With the electrification of the transport sector, the importance of nickel as a cathode raw material in lithium-ion batteries is increasing, mainly due to the metal's high energy density and storage capacity.[63] However, compared to other applications such as stainless steel and steel refining, the use of nickel in batteries still plays a subordinate role (Figure 6).[64]

Although the EU's nickel supply has historically been well diversified, there is a high concentration of ownership in the mining and processing of nickel. Nickel has therefore been included in the European Commission's list of Critical Raw Materials for 2023.[65]

v Additional demand of 5.48 million tonnes in 2040 in the future technologies studied, an increase of 137 percent compared to 2018.

vi In the report, renewable technologies include PV solar systems, wind turbines, electrolysers, batteries, fuel cells, and heat pumps for residential applications.

Future use of nickel

The demand for nickel is expected to increase significantly in the future, both in Germany and globally.[66] The forecast growth in demand from renewable energy technologies will exceed almost all other areas of application: according to the IEA's *'Net Zero Emissions by 2050 Scenario'*, a total of 6.2 million tonnes of nickel will be required worldwide in 2050, of which 3.8 million tonnes, or more than 60 percent, will be needed for renewable energy technologies.[67]

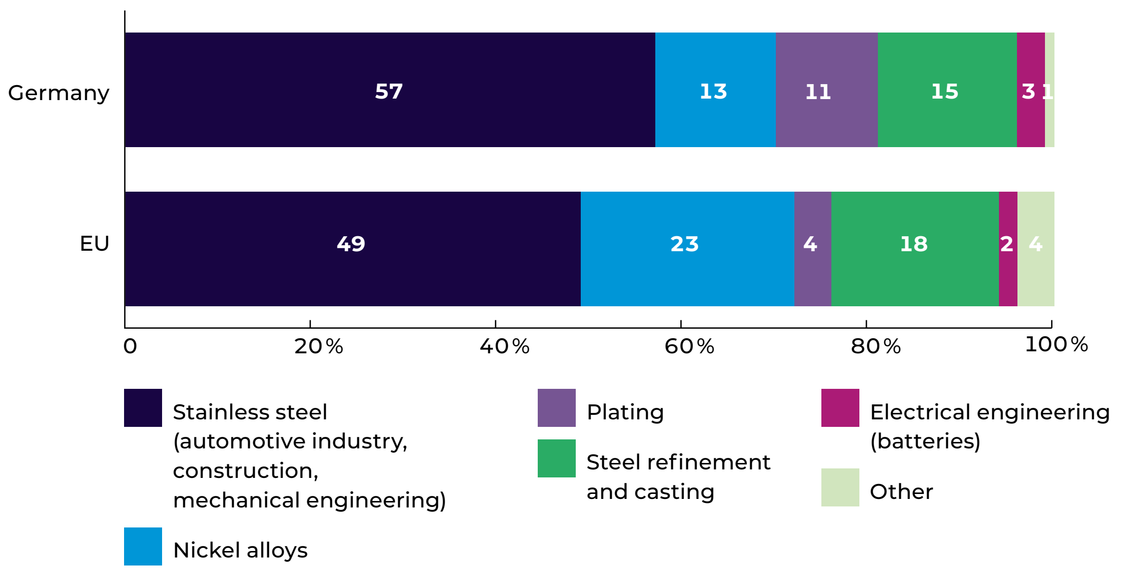
Following the ambitious sustainability path, the DERA study forecasts a global nickel demand of 1.28 million tonnes in 2040 for the future technologies studied. This represents an almost sevenfold increase compared to 2018 (187,560 tonnes) and is mainly due to the use of nickel in solid-state battery cells in electromobility applications. Here, the trend in lithium-ion batteries is towards higher nickel and lower cobalt contents.[68] On average, around 40 kilograms of nickel are used in electric cars,[69] with the batteries consisting of just under 16 percent nickel.[70] Global demand for nickel is also growing strongly due to its use in water electrolysis and superalloys.[71]

Nickel is used in 14 of the EU's 15 strategic technologies. Demand for nickel is expected to grow particularly strongly: EU demand for the analysed technologies is expected to increase tenfold by 2030. From a nickel demand of 28,000 tonnes in 2020, consumption is expected to be between 225,000 and 286,000 tonnes in 2030 – and as much as 317,000 to 455,000 tonnes in 2050. On average, this represents an increase by a factor of 20. Nickel demand is almost entirely driven by lithium-ion batteries, which will require between 214,000 and 266,000 tonnes of nickel in 2030 alone. A further 5,800 to 12,300 tonnes of nickel will be required for wind turbines in 2030.[72]

In Germany, nickel will play an increasingly important role in the future, especially in vehicles and batteries, ICT and household appliances, as well as in building and civil engineering.[73] In addition, more than 3,000 tonnes of nickel will be needed annually in Germany for the necessary expansion of wind turbines (Figure 3).

Figure 6 – Use of nickel in Germany and the EU in 2020

Source: Own figure based on Dittrich et al., 2024



Potential for reduction

Private transport generates many land use conflicts around the world, whether in the distribution of space in cities or in the extraction of the required raw materials when agricultural land is destroyed or water becomes scarce.
Photo: Jens Herrndorf, Unsplash

As shown before, the bulk metals mentioned will continue to be needed in many areas in the future. At the same time, a closer analysis of their current use reveals significant potential for reduction. From PowerShift's perspective, this potential must be exploited to address the social and environmental challenges associated with the extraction of metallic raw materials. At the same time, a reduction in today's inequitable global consumption will ensure security of supply for the industry and reduce production losses due to fragile supply chains. On behalf of PowerShift, the ifeu Institute has therefore analysed various sectors and their reduction potentials, which are presented below. These estimates and the underlying calculations are described in detail in the ifeu Institute's short study *'Nutzung von Basismetallen in Deutschland und der EU und Reduktionspotentiale'* (*'Utilisation of base metals in Germany and the EU and reduction potentials'*).

Reduction potential in the transport sector

In 2019, the base metals iron and steel, copper, nickel and aluminium together accounted for more than 80 percent of all metals used in vehicles.[vii] Iron and steel alone accounted for half of this (Figure 7). In total, the consumption of metallic raw materials for the mobility sector in Germany amounted to around 28 million tonnes of RME in that year. Before exports are deducted, the use of metallic raw materials in Germany even amounted to about 81 million tonnes of RME. Motor vehicles were responsible for about 90 percent of the metals used in the mobility sector.[viii]

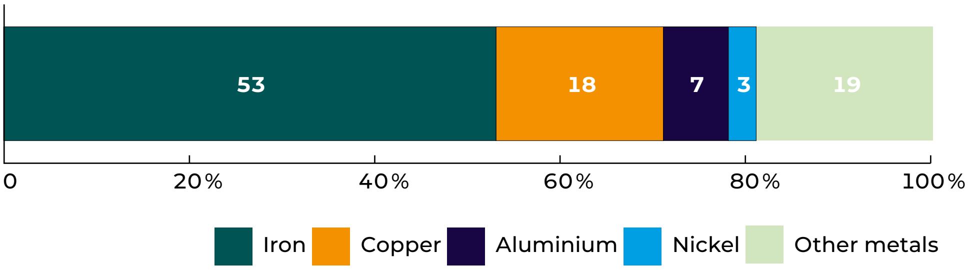
For some time now, there has been a trend towards larger vehicles: while the number of smaller cars has increased by only two percent over the last decade, the number of large vehicle types such as SUVs has increased by 80 percent.[74] Since 2003, the unladen weight of newly registered cars has increased by 23 percent. In 2022, the average weight of passenger cars was around 1.7 tonnes, compared to around 230 kilograms less in 2010. This is due to the increase in vehicle size,[ix] as well as additional safety and comfort features and electrification. Due to their heavy batteries, electric cars weigh thirteen percent[75] more than petrol or diesel cars in the same class.

vii In this analysis, the raw material requirements are considered including their raw material backpack – i.e. in raw material equivalents. An analysis of the exclusive product or metal weights would lead to an even higher proportion of base metals.

viii Ships' share of raw material consumption: six percent; rail and air transport: four percent each

ix For example, the Opel Corsa F (from 2019) is 24 cm longer and 12 cm wider than the Corsa C (until 2003).

Figure 7 – Share of metals in the consumption of metallic raw materials in the transport equipment category in 2019 Source: Own figure based on ifeu, 2023 and Lutter et al., 2022



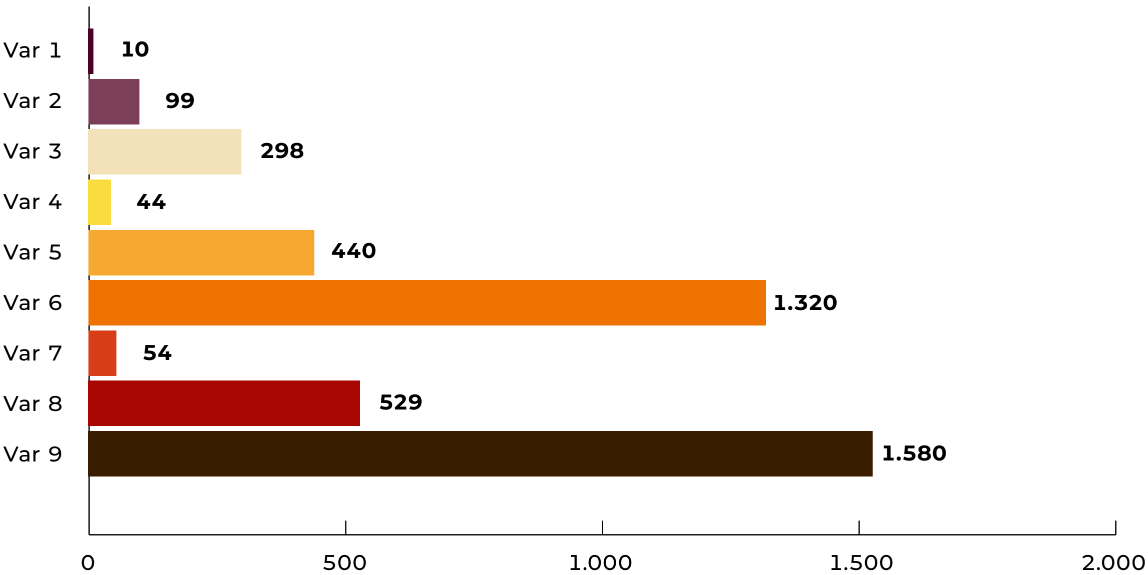
This high metal consumption could be significantly reduced if both the number and weight of newly registered vehicles were to fall in the future. This is shown in a study by the ifeu Institute, which examined the potential material savings compared to the status quo for nine different variants of a shift in vehicle segments in favour of smaller vehicles and a reduction in new registrations (Figure 8).

Without changes in vehicle sizes and new registrations, the cumulative material demand for the four base metals is assumed to be around 104 million tonnes by 2050.

Although there are almost 49 million cars in Germany,[76] they are rarely driven: On average, each vehicle is parked for about 23 hours per day.[77] The utilisation rate of vehicles is therefore only two percent. Despite this, around three million new vehicles are registered every year. Particularly large metal savings could be achieved if instead the number of new registrations were reduced by 30 percent each year. This would result in a reduction in material demand of around 31.2 million tonnes by 2050 (Var 6). A ten percent reduction in new registrations per year would save 10.4 million tonnes of iron and steel, aluminium, copper, and nickel by 2050 (Var 5). Reducing new car registrations is therefore an important lever for saving base metals (Figure 9).

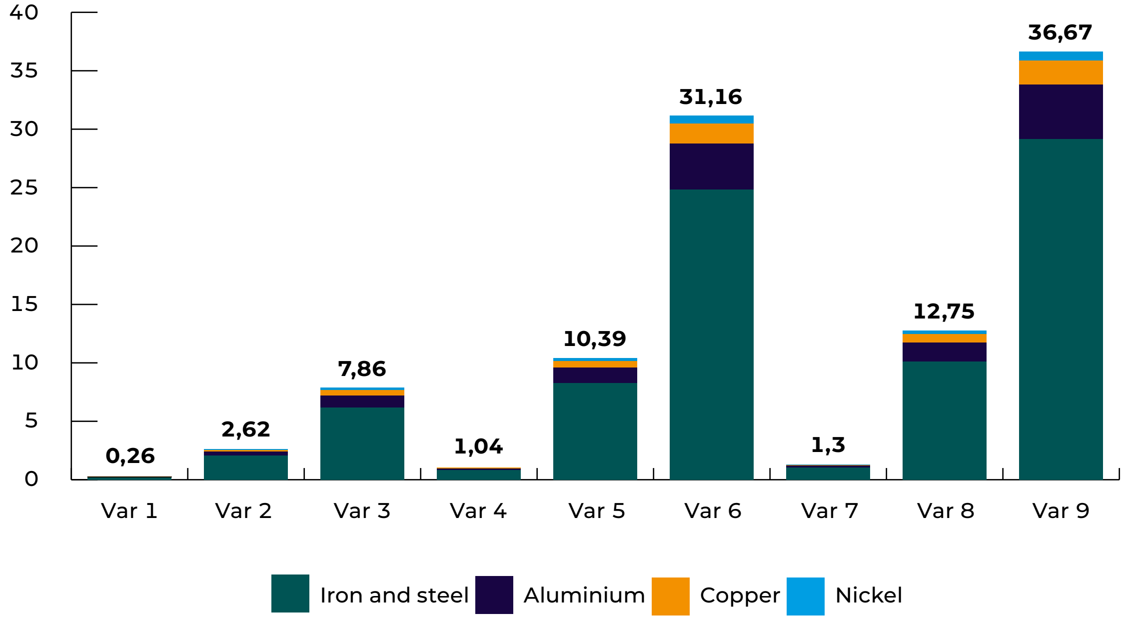
Figure 8 – Material savings of variants 1 to 9 compared to status quo demand for selected years in 1000 tonnes[x]

Source: Own figure based on Dittrich et al, 2024



x Var 1-3: of the new registrations of medium and large vehicles, one percent (Var 1), ten percent (Var 2), or 30 percent (Var 3) are shifted to the small vehicle segment each year;
Var 4-6: new registrations decrease by one percent (Var 4), ten percent (Var 5), or 30 percent (Var 6) per year;
Var 7-9: Combination of measures:
Var 7 = one percent redistribution of new registrations to the small car segment + one percent annual reduction in new registrations;
Var 8 = ten percent redistribution of new registrations to the small car segment + ten percent annual reduction in new registrations;
Var 9 = 30 percent redistribution of new registrations to the small car segment + 30 percent annual reduction in new registrations.

Figure 9 – Cumulative material savings of variations 1 to 9 from 2025 to 2050 compared to status quo demand, differentiated by base metal, in Mio. Tonnen
Source: Own figure based on Dittrich et al., 2024



There is also relevant reduction potential in shifting new registrations from the medium and large car segment to the small car segment: If 30 percent of new registrations are shifted to small cars each year, this will reduce metal demand for the four base metals by 7.8 million tonnes by 2050 (Var 3). Even with a weaker trend in this direction, where the share of small cars in new registrations would only increase by ten percent, around 2.6 million tonnes of the four base metals could be saved by 2050 (Var 2) (Figure 9).

The most significant savings potential lies in the combination of measures: reducing new car registrations by ten percent per year and shifting ten percent of passenger cars to the small car segment could save around 12.7 million tonnes of the base metals studied by 2050 (Var 8). By far the largest reduction in metal consumption would be achieved by the very ambitious shift of 30 percent of large and medium cars to the small car segment, combined with a 30 percent reduction in annual new registrations (Var 9): This would save a total of around 36.7 million tonnes of the four base metals by 2050 – including around 30 million tonnes of iron and steel, 4.6 million tonnes of aluminium, two million tonnes of copper, and 800,000 tonnes of nickel (Figure 9).

Potential for reduction in the construction sector

In 2020 alone, almost four million tonnes of metals were consumed for the construction of 260,000 residential units. From 2025 onwards, the target of 400,000 housing units per year is to be achieved, which would mean an annual metal demand of almost five million tonnes – of which around 4.6 million tonnes of steel, 60,000 tonnes of copper and 45,000 tonnes of aluminium, as well as almost 270,000 tonnes of other metals such as zinc. Total metal consumption between 2025 and 2050 would therefore be around 128 million tonnes of metals.

According to the WWF's *'Circular Economy Model Germany'* study, the greatest potential for saving raw materials – metallic and non-metallic – lies in the building sector, with the key lever being the reduction of residential and office space and the longer use of existing buildings.

In recent years, the share of multi-family dwellings (MFD) among new buildings has increased slightly. Compared to single-family dwellings (SFDs), which require around 400 tonnes of materials each, the material requirement for MFDs is much lower at 270 tonnes. This is mainly due to the smaller average size of housing units in multi-family dwellings and the shared use of staircases, basements and other areas.[78] Metals account for around four to five percent of the total material requirements, with steel accounting for 93 percent and copper and aluminium each accounting for one percent.[79]

If the construction of single-family dwellings declines in favour of multiple-family dwellings in the coming years, large quantities of metallic raw materials could be saved: according to calculations by the ifeu

Institute, just doubling the decline in SFDs from around two to four percent per year would save around 1.4 million tonnes of metals by 2050 compared to the status quo (see variant 1, Figure 10).

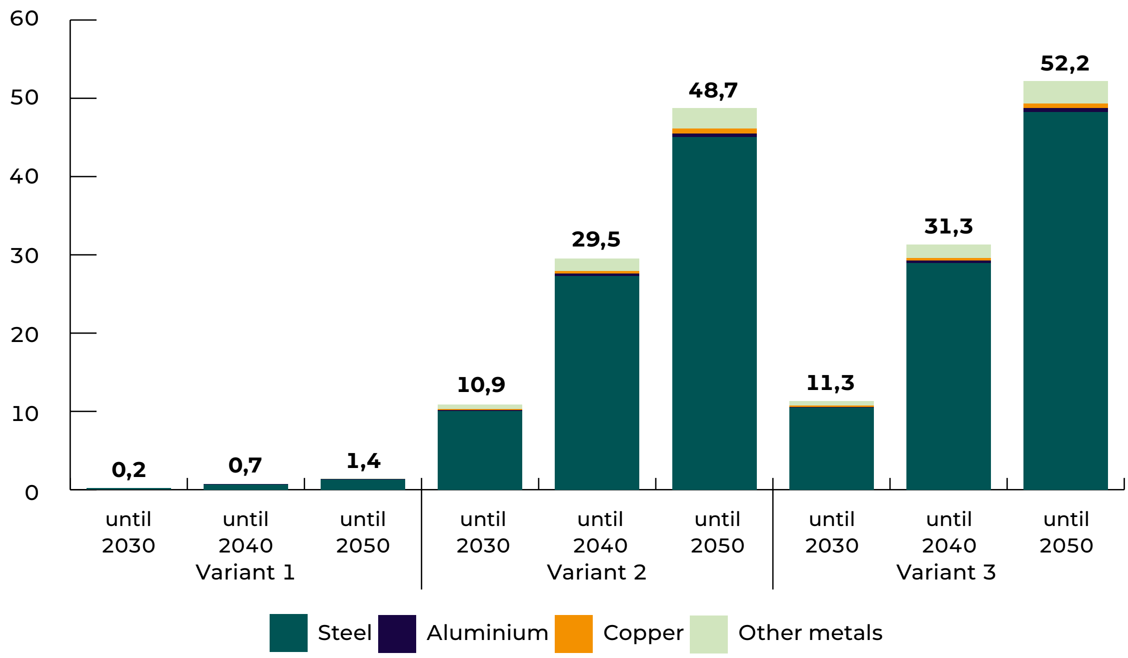
Another lever for saving metallic raw materials in the construction sector would be to reduce the average living space, which has in fact slightly increased in recent years: Compared to 2011, a person has 1.6 m² more living space in 2021 (average 47.7 m²).[80] However, this has not led to an increase in housing satisfaction, which has remained constant since 2005, when the average living space was around 41.2 m².[81] On this basis, the ifeu Institute has analysed the metal savings that could be achieved by reducing the average living space per person to 35 m² (average living space in Germany in 1992). According to this, a total of around 48.7 million tonnes of metals could be saved by 2050 – including around 45 million tonnes of steel, 5.9 million tonnes of nickel, and 4.4 million tonnes of aluminium (see variant 2, Figure 10).

The combination of the two measures offers even greater potential savings: by increasing the share of new MFDs and simultaneously reducing the average living area, some 52.2 million tonnes of metals can be saved by 2050 (see variant 3, Figure 10). Compared to the status quo (cumulative metal consumption of 128 million tonnes by 2050), this represents a significant reduction in demand for (metallic) raw materials.

Considerable savings can therefore be achieved by exploiting the reduction potential in new buildings. In addition, however, there are a number of sufficiency approaches that can significantly reduce the need for new construction, including the use of vacant space, the conversion of office space, the subdivision of detached and semi-detached houses, and the addition of storeys to buildings.[82] Zimmermann et al. (2023) conclude that the annual need for new construction could be significantly reduced by consistently implementing these sufficiency measures: 114,000 dwellings could be created by adding storeys to buildings, 100,000 by converting office space, 98,000 by dividing detached houses, and a further 18,000 by using vacant land (Figure 11). Instead of the planned 400,000 new dwellings, only 70,000 new dwellings would need to be built each year to meet housing demand.

Figure 10 – Cumulative metal savings in million tonnes of metal compared to the status quo (from 2025) for variants 1 to 3, in Mio. Tonnen Metall[i]

Source: Own figure based on Dittrich et al., 2024



i Variant 1: The proportion of SFDs among new dwellings continues to fall. The decline doubles from the current two to four percent per year (decrease in favour of MFDs).
Variant 2: The average living space per person decreases from 47 m² to 35 m² for all new dwellings.
Variant 3: Combination of measures: The average living space per person is reduced to 35 m², while at the same time the proportion of MFDs among new residential units increases.

Shared living in multi-family dwellings is comparatively resource-efficient.
Photo: Sigmund, Unsplash

Although metallic raw materials would also be required for the various conversion measures in the sufficiency scenario, the total annual demand for the measures examined would only be around 360,000 tonnes. Including the construction of 70,000 new dwellings, the annual metal demand would be 1.54 million tonnes, which is still much lower than the status quo. In total, 69 percent of metal raw materials could be saved compared to the 4.96 million tonnes in the status quo (Figure 12). Compared to the status quo, the annual metal requirement in the sufficiency scenario is less than a third (31 percent).

Windows are another starting point for potential savings in the use of raw materials. Around one fifth of the windows produced in Germany in 2016 were aluminium windows, with an average aluminium content of 25 percent by weight. Aluminium is also used in wood-aluminium windows (nine percent of windows produced in Germany in 2016), accounting for six percent by weight, and in small quantities in timber windows (16 percent of windows produced in Germany in 2016; one percent aluminium by weight). Only the most commonly used plastic windows (54 percent of windows produced in Germany in 2016) do not contain aluminium, but steel sheet (20 percent).[83] According to calculations by the ifeu Institute, a significant amount of aluminium could be saved if aluminium windows were replaced by the other three window types. The use of aluminium would fall by around 95 percent, while the demand for sheet steel would increase slightly due to the increased use of plastic windows. Overall, however, this measure could save a good third of the raw material equivalents (178,480 tonnes out of 453,000 tonnes RME of the base metals studied).

Figure 11 – Number of dwelling units (DU) in the sufficiency scenario and specific metal requirements Source: Own figure based on Dittrich et al., 2024

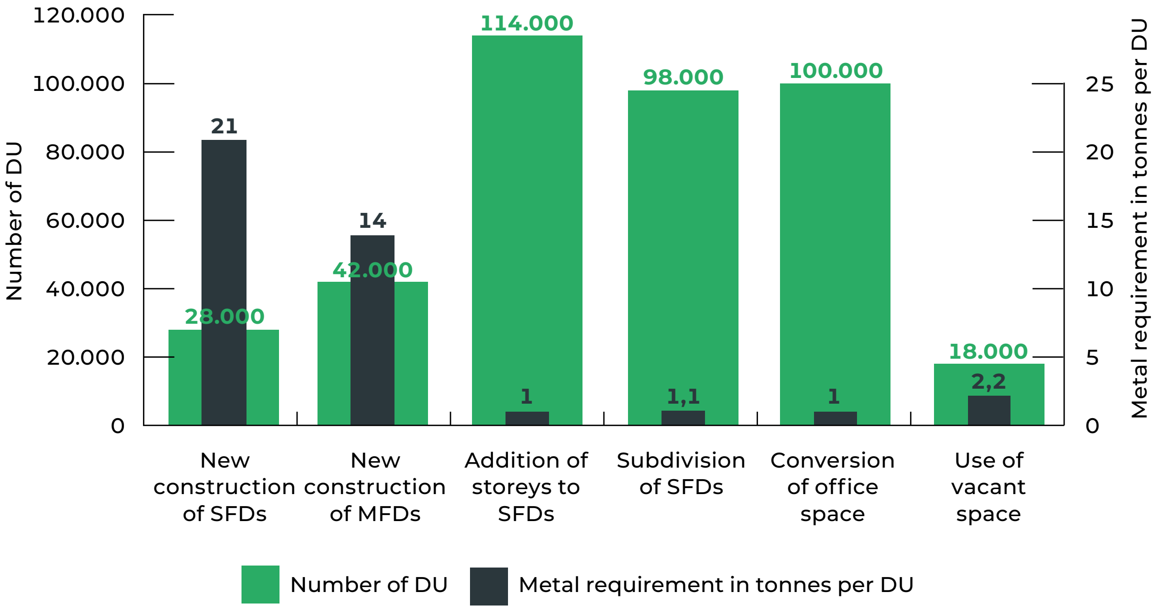
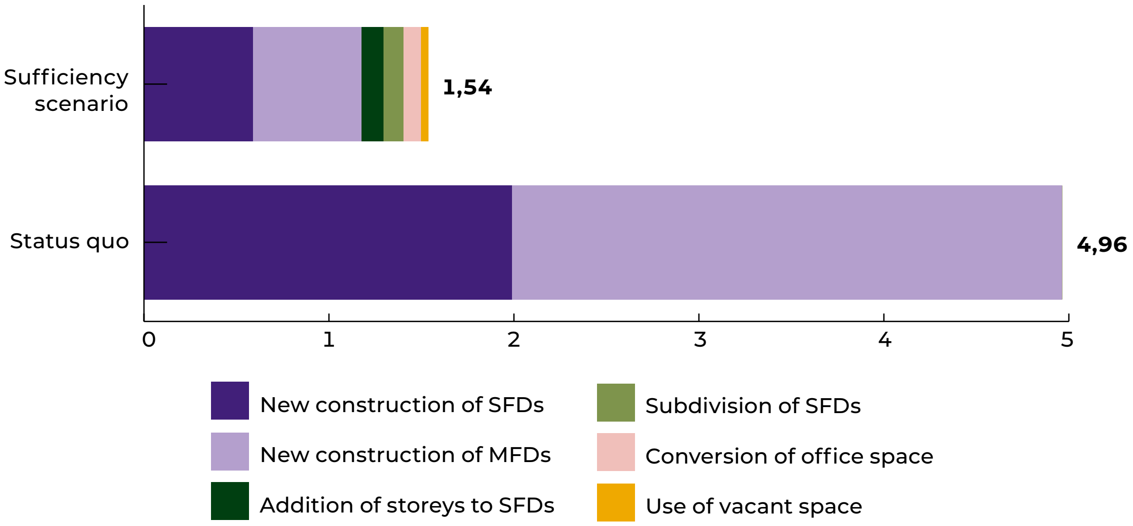


Figure 12 – Metal demand in the sufficiency scenario and in the status quo in 2025, in Mio. Tonnen Source: Own figure based on Dittrich et al., 2024



Metal recycling potential

Significant quantities of primary metals can be saved by recycling aluminium, copper, iron, and steel. Copper recycling alone has so far saved around 12.4 million tonnes of RME in Germany compared to a raw material situation based on primary copper alone (Table 1).[84] In 2010, around 46 percent of copper demand was covered by the use of secondary copper.[85] Recycling and the use of secondary aluminium saves about 1.6 million tonnes of RME, with the secondary use rate in 2010 being about 54 percent. The use of secondary iron is around 33 percent (2010), which means that German raw material consumption can be reduced by around 8.7 million tonnes of RME compared to a situation based on primary iron alone.[86]

Increased recycling of copper, aluminium, iron, and steel scrap could theoretically save large quantities of primary metals, thereby reducing CO_2 emissions and conserving water and land. However, an as yet unpublished study by Dittrich et al. found that the scrap metal actually available and recycled in Germany is not sufficient to significantly increase the use of secondary metals in copper and aluminium. This means that the copper scrap actually available can only achieve a secondary use rate for copper of a maximum of 49 percent by 2030 and 59 percent by 2050. A secondary copper use rate of 59 percent would reduce total raw material consumption in Germany by a further 800,000 tonnes of RME. However, compared to the current use of secondary copper of 46 percent, the further savings potential for primary copper through an increase in the use of recycled copper, which is considered realistic, is rather small. The situation is similar for aluminium: the share of end-of-life aluminium scrap in Germany, which is considered to be the maximum possible, is estimated at 67 percent for both 2030 and 2050, which is not much higher than the secondary recycling rate of 54 percent in 2010. Achieving this 67 percent could save a further 350,000 tonnes of RME compared to the status quo.[87]

In contrast, there is much greater potential for savings in the use of primary raw materials for iron and steel. According to Dittrich et al. (unpublished), a feasible secondary use rate of 63 percent can be assumed for Germany by 2030, rising to around 75 percent by 2050. Compared to the current level of secondary energy use (approx. 33 percent in 2010), this represents a significant increase. A secondary use rate of 75 percent could reduce Germany's annual raw material consumption by a further 15 million tonnes of RME.[88]

Copper scrap is already being recycled in large quantities. Photo: Andrew Stowe, iStock

Table 1 – (Possible) saving of primary metals through the use of secondary metals
Source: Own table based on Dittrich et al., 2024

	Copper	Aluminium	Iron
Use of secondary metals in 2010	56 percent	54 percent	33 percent
Primary metal savings in tonnes of RME	12.400.000	1.600.000	8.700.000
Potential rate of secondary use by 2050	59 percent	67 percent	75 percent
Further primary metal savings in tonnes of RME	800.000	350.000	15.000.000

The reduction in the use of primary metals and the resulting reduction in environmental impacts (CO_2 emissions, freshwater use, and land use) is linked to the availability of secondary metals. This potential can only be realised if the recycling sector is expanded.

Increasing recycling of new technologies

It is also very important to recover the metals contained in wind turbines, photovoltaic systems, and batteries at the end of their life cycle. This scrap from renewable energy technologies is expected to increase 30-fold in the next few years.[89] By 2030, the EU is expected to generate 1.5 million tonnes of end-of-life scrap from PV systems, 4.75 million tonnes from wind turbines, and 240,000 tonnes from energy storage systems in the mobility sector – including around 173,000 tonnes of aluminium, 153,000 tonnes of copper, and 19,000 tonnes of nickel.[90] In 2030, these three energy technologies are therefore expected to account for around 32,000 tonnes of aluminium, 28,300 tonnes of copper, and 3,500 tonnes of nickel in Germany, which can be returned to a new production process as end-of-life scrap.[91]

However, one challenge is that there is currently little experience of recycling wind turbines and solar cells in the EU, as few systems will have reached the end of their life in the 2020s.

Reduction potential by extending the life of goods

A doubling of demand for goods in Germany would result in a significant increase in metal demand of around 52 percent, corresponding to around 84 million tonnes of RME.[92] The premature disposal of products that could still be used if repaired generates about 35 million tonnes of waste each year in the EU. It is estimated that 30 million tonnes of resources are wasted and around 260 million tonnes of greenhouse gases are emitted as a result.[93]

The number of digital and mostly short-lived devices, such as laptops and smartphones, has risen sharply over the past two decades. Around 41 percent of these information and communication technology (ICT) devices are made of metal raw materials and account for around ten percent of Germany's metal consumption.[94] Assuming that demand for ICT devices in private households can be halved by doubling their useful life through various measures, this would save around 1.13 million tonnes of RME metals in Germany – including around 280,000 tonnes of copper, 140,000 tonnes of iron, 105,000 tonnes of aluminium, and 22,000 tonnes of nickel. Measures to extend the useful life of goods can therefore significantly reduce the consumption of raw materials: the longer goods are used, the longer there is no demand for substitutes (without taking into account rebound effects).[95]

Other potential savings

There is also significant potential to reduce the consumption of these base metals in other areas where large quantities of iron, steel, aluminium, copper, and nickel are used. The ifeu study looked at the healthcare sector as an example, as it produces large amounts of waste (around 4.8 million tonnes per year) – including many metals used in the form of instruments, metal packaging, implants, or electronic devices, for example.[96] The use of disposable products in particular contributes to the high volume of waste. The Fraunhofer Institute for Materials Recycling and Resource Strategies (IWKS) estimates that 8,000 tonnes of disposable chromium steel instruments are thrown away every year in German hospitals alone. As a rule, this waste is not collected separately, which means that the metal recovered after melting down can often only be used as construction steel, where the alloy no longer plays a role. There are individual projects to prevent this downcycling, such as the SReS® collection system being developed by the Institute for Recycling, Ecology and Design (IRED) together

Example: Extended use of smartphones

21.6 million smartphones were sold in Germany in 2022.[137] Around 82 percent of the metal content of smartphones consists of the base metals copper, aluminium, iron, and steel. The remaining 18 percent is made up of cobalt, magnesium, palladium, and indium.

Within the EU, smartphones are used for an average of around two to three years.[i] A useful life of two years is assumed for Germany as this corresponds to the usual duration of software support and the usual duration of mobile phone contracts, at the beginning of which new smartphones are often purchased.[138] Although the amount of raw materials required for a single smartphone remains manageable due to its light weight, this short average useful life combined with high sales figures results in a significant overall consumption of metallic raw materials. Due to the complex processing involved, only a small proportion of the metals used in smartphones are recycled.[139]

Comparing the actual raw material demand with an alternative scenario in which the average service life of smartphones in Germany doubles from two to four years, the total annual metal demand for the base metals analysed is halved from 33,534 tonnes of RME to 16,767 tonnes of RME: 14,661 tonnes of RME copper, 1,814 tonnes of RME aluminium, and 291 tonnes of RME steel are saved.[140]

Significant savings potential can also be expected for other ICT equipment by extending its useful life – however, the specific savings depend, among other things, on the recycling potential of the components, the composition and sales volume of the equipment, and the current useful life and vary greatly between different ICT equipment. For example, laptops, which on average have a longer life than smartphones, are easier to repair due to their design, and have longer software support, require different measures to achieve a doubling of their life cycle.[141]

i This is based on the first use phase of smartphones and does not take into account the second-hand market, which has strong growth potential.

with the Fraunhofer project group IWKS, which aims to separately collect and recycle disposable metal cutlery.[97]

In addition to the healthcare sector, there are also various opportunities to reduce the use of base metals in the packaging industry. In Germany, 13 percent of aluminium is used in this sector (see Figure 4). In particular, the recycling of aluminium waste from households often results in downcycling, as the aluminium contained in this waste comes in many different compositions, making it difficult to recycle by type.[98] The savings that could be achieved through specific measures to improve the recycling of aluminium waste or through bans on single-use packaging and single-use products in general, such as disposable batteries and e-cigarettes, need to be further investigated.

Policy measures

In repair cafés, people learn from each other how to fix defective appliances. The right to repair, which was agreed at EU level at the beginning of 2024, is intended to simplify repairs. Photo: Inga Klas, Pixabay

German society as a whole consumes a lot of raw materials, including metals. We consume far more than is fair on a global scale.[99] In recent years, awareness of the impact of metal consumption has increased significantly. However, media reports and civil society activities very often focus on other metals such as lithium or cobalt. This is not enough. After all, base metals also cause massive environmental damage, the potential environmental hazards – i.e. the ecological risks associated with their extraction – are in some cases significantly higher, and our overconsumption is at the expense of the fair use of raw materials internationally and in the future. The negative social and environmental impacts of resource extraction underline this need and must be addressed by society as a whole. This means that while changes in individual behaviour have a role to play, the responsibility does not lie with individuals alone, but with society as a whole. This is where policy instruments and measures come into play, which provide a framework for societal developments and can be implemented much faster and be more effective than mere appeals to individuals.

Policy measures to reduce metal consumption in the two areas mobility and housing have a special role to play. They have an enormous leverage effect on the quantities used. In its coalition agreement, the German government proclaimed *'the goal of reducing the consumption of primary raw materials and creating closed material cycles'*. In the following, the federal ministries have therefore been assigned individual measures to be implemented within their respective areas of responsibility:

Federal Ministry for Digital and Transport (BMDV)

1. Smaller and lighter cars

A joint study by the Global Fuel Economy Initiative in collaboration with the FIA Foundation, the UN Environment Programme (UNEP), the IEA, and others calls for *'The introduction of a cap on the footprint of vehicles, both in absolute terms and as a sales-weighted average, coupled with future net reductions to limit and then reverse the shift to SUVs.'*[100] According to the study by the ifeu Institute, there are also significant levers for saving raw materials and reducing the environmental and social challenges associated with their extraction. The BMDV should therefore create a framework for making cars smaller and lighter again. A shift from SUVs and midsize cars to small cars by shifting 30 percent of registrations to the small car segment each year could result in savings of 7.8 million tonnes of iron, aluminium, copper and nickel by 2050 (see chapter *'Reduction potential in the transport sector'*).

In order to address this reduction in average car weights and initiate a shift towards small cars, appropriately adapted bonus-malus systems[101] are needed, such as those that exist in France, for example. There, a weight penalty tax is levied on particularly heavy internal combustion engines. This tax is paid once when a car is first registered. From 1 January 2024, the weight penalty tax applies to vehicles weighing 1.6 tonnes or more and increases progressively. Vehicles weighing more than 1.6 tonnes are charged ten euros per kilogram, from 1.8 tonnes 15 euros, from 1.9 tonnes 20 euros, from two tonnes 25 euros, and from 2.1 tonnes 30 euros. There are also discounts for families with many children.[102] The aim is clear: particularly large, heavy, and polluting cars must become less (economically) attractive. Another option is to levy higher parking charges, as recently decided in Paris.[103]

The Global Fuel Economy Initiative, in collaboration with UNEP and the IEA, is also proposing reforms to vehicle taxation. In addition to weight, sales prices should also be used as a control parameter.[104] In addition, the expansion of the charging infrastructure should be planned in a way that makes it attractive to use electric cars with a shorter range. This is because shorter ranges mean smaller and lighter batteries and ultimately have a positive impact on the quantity of base metals used.

It is important that the revenue from these taxes and charges is returned in a socially responsible way. *'Climate money'* is one way of doing this, as is investment in the rail network, public transport, cycling, and walking. Money should also be used to support the *'Deutschland-Ticket'* to further reduce its price and make public transport more attractive.

2. Shared use and reduction in the total number of cars

Many people in Germany look enviously at Paris, London, Copenhagen, and Amsterdam. This is because these cities have initiated mobility changes, supported public transport, and prioritised walking and cycling in urban planning. Reducing the number of new car registrations by 30 percent per year could reduce the demand for iron, aluminium, copper, and nickel by almost 31.2 million tonnes by 2050 (see chapter *'Reduction potential in the transport sector'*). Reducing the number of new car registrations is therefore a highly effective measure for reducing metal demand for the base metals analysed, as well as for many Critical Raw Materials.

There are various *'push and pull'* measures to reduce the number of cars on the road. On the one hand, increasing the attractiveness of public transport, as mentioned before, and taking greater account of and promoting less resource-intensive modes of transport will help.[105] In addition, various forms of car-sharing need to be promoted so that not owning a car becomes an attractive option for many people. People of all ages and with and without disabilities must be considered and kept mobile.

Push factors are also needed. Cities such as Oslo will ban cars with internal combustion engines from the city centre from 2025.[106] Access restrictions, toll systems, and the removal of (free) parking facilities are ways of responding at the local level. The systematic prioritisation of cars in urban planning, traffic regulations, and infrastructure funding should end.[107] Environmentally harmful subsidies, such as the *'diesel privilege'*, must also be systematically removed. Ending tax breaks for company cars could also save billions of euros in taxes each year.[108]

3. Promoting durability and reuse

In addition to reducing the number and size of vehicles, there is a need to ensure that they last as long as possible, for example through durable design, long-lasting materials, and regular maintenance, as well as increased reuse (remanufacturing). The European Battery Regulation is an important step in this direction, with specific requirements for the recycling of battery raw materials. It sets

A reduction in new registrations and a shift to smaller and lighter electric cars could significantly reduce the need for metal in the transport sector.
Photo: andreas160578, Pixabay

In some regions of Germany, ten per cent of dwellings are vacant: to counteract these vacancies, life away from the major cities must become more attractive.
Photo: Ploegerson, Unsplash

minimum recycled content requirements for industrial batteries, electric vehicle batteries, light vehicle batteries, and starter batteries containing cobalt, lead, lithium or nickel, in the active materials from 18 August 2036. In the case of nickel, this must be at least 15 percent. The Regulation also sets targets for the recycling of these batteries. For example, 90 percent of copper and nickel must be recycled by 31 December 2027, and up to 95 percent by 31 December 2031.[109]

However, it is not only battery production that needs to be transformed into a circular economy, but also the entire automotive production process. This means that aspects such as recycling and durability need to be prioritised as part of ecological product design. These measures need to be better integrated into current and future policies and legislative processes at national and EU level. For example, the regulation on the recycling of end-of-life vehicles should set binding minimum quotas for the reuse of vehicle parts and oblige manufacturers to facilitate the dismantling of all (reusable) vehicle parts. The scope of the regulation should also be extended to other types of vehicles[xi] and ambitious quotas should be set for the minimum proportion of recycled steel and aluminium.[110]

xi According to the Commission's current draft, most of the regulation's measures would only apply to vehicles with a maximum of eight seats and a maximum total mass of 3.5 tonnes. Larger vehicles, motorcycles, quads, and trailers would be exempt.

Federal Ministry of Housing, Urban Development, and Building (BMWSB)

1. Better use and development of existing properties

While housing shortages are worsening in many major cities and rents are rising rapidly, there are large numbers of empty homes in some parts of Germany, particularly in rural areas. Ten of the 16 federal states have regions with a vacancy rate of more than eight percent.[111] In the four largest cities (Berlin, Hamburg, Munich, and Cologne), there were also around 16,770 empty homes in 2022, according to Statista.[112] Other calculations based on microcensus figures put the number of (temporary) vacancies at between 25,000 and 47,000 in Munich alone.[113] In the Netherlands, for example, fines of up to €9,000 can be imposed to prevent vacancies. The conversion of unused office buildings, churches, old schools, and hospitals is also encouraged in the Netherlands.[114] The BMWSB should investigate to what extent such conversions are also possible in Germany. In 2022 alone, 740,000 square metres of office space were vacant in Berlin.[115] Given the average size of an apartment of 92.1 square metres,[116] this office vacancy would be the equivalent of around 8,000 apartments. Changing working habits and an increase in home working could see this proportion rise even further in the future.

Unsurprisingly, the greatest potential for resource savings in the construction sector lies in the reduction of residential and office space.[117] Various measures, such as using existing vacant buildings in rural areas, could significantly reduce the need for new construction: all in all, the consistent implementation of the sufficiency approaches examined by Zimmermann et al. (2023) could lead to enormous savings of 3.42 million tonnes of metallic raw materials per year (see chapter *'Potential for reduction in the construction sector'*). To promote these approaches, the BMWSB should develop a National Efficiency and Sufficiency Strategy for Buildings, which should include the implementation of a nationwide campaign. In addition, national standards need to be set and building and planning laws need to be adapted to give priority to sufficiency approaches in the construction sector over new buildings and the development of new land.[118]

In general, measures to develop existing buildings, including the addition of storeys to residential and non-residential buildings and the extension of the life of buildings through renovation, should be given priority over new construction and should be implemented in a socially equitable manner. A permit requirement for demolitions, subject to an environmental and climate impact assessment, is also a possible instrument.[119] In addition, the extent to which brownfield sites and gaps between buildings can be developed should be explored, rather than the more resource-intensive development of new areas outside the city centre.[120]

2. Needs-orientated use of living space

Older people, in particular, often live in homes that they do not use sufficiently, for example when their children have moved out or they live alone. This is the result of a survey in Münsterland, Germany, in which 51 percent of respondents said they no longer use at least one room, 80 percent of them two or more rooms.[121] Due to the shortage of housing, smaller flats are often not available or are just as expensive or even more expensive than the current flat due to a significant increase in rents. At the same time, experience from co-operatives shows that opportunities to swap flats are offered and taken up. Municipalities, provinces and the state should therefore do more to promote cooperative housing and take measures to make it easier to move to smaller flats, to swap flats, to add other people to the household, to separate a residential unit, and to split detached or semi-detached houses.

3. Reduction potential for new builds

It is not always possible to avoid new construction by upgrading the existing stock. However, compromises have to be made to ensure that the new buildings can be used as long, efficiently, and flexibly as possible.

In order to conserve raw materials, the trend of recent decades to increase the share of multiple-family dwellings in the total building stock must be continued and expanded. In addition, new buildings should take up as little space as possible. Living in single-family dwellings, which require significantly more raw materials and space per unit than apartment buildings, must therefore become less attractive. As shown in the chapter *'Potential for reduction in the construction sector'*, even a slight increase in the trend towards multiple-family dwellings could save around 1.4 million tonnes of metals by 2050.

At the same time, measures should be taken to reduce the average living space of 47.7 m². Bringing it back to around 1993 levels (35.4 m² per person) could save around 48.7 million tonnes of metals by 2050. However, even a slight reduction in the average living space – for example to 41.2 m², after which living satisfaction would no longer increase anyway – could avoid correspondingly large quantities of metallic raw materials. In order to achieve this, forms of living where, for example, communal areas are shared would have to become more attractive. However, the demand for a reduction in average living space cannot affect everyone equally and must not be based on (economic or social) coercion, but should instead aim to reduce unused space and use potential. In order to ensure that buildings last as long as possible, it is important to anticipate future, changing use requirements and framework conditions during construction – after all, the demands on a building can change over time. With this in mind, opportunities for adaptability, such as modular construction methods, should be promoted to allow for more flexible space design.[122] These can also offer environmental advantages over conventional buildings.

The reuse of structural steel and components is also important to reduce the amount of raw materials needed for new buildings, for example through appropriate design and the use of standardised components that are easy to dismantle and recycle. Design that encourages less over-specification and lightweight construction can also reduce the need for structural steel and structural concrete.[123] To reduce the use of metallic raw materials, policy measures are also recommended to promote the use of alternative building materials through adapted regulations and subsidies such as purchase premiums. These could be used, for example, to reduce the use of aluminium in window frames and thus the use of base metals in window construction. Further research is needed to investigate what other interactions a shift from aluminium window frames to wood or plastic windows would have.

A tax on primary building materials, as is being discussed for mineral raw materials,[124] should also be considered for metallic raw materials. The UBA assumes a cost increase of 0.3 percent for mineral raw materials.[125]

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection (BMUV)

1. Increasing the use of secondary metals

The BMUV is currently working on a National Circular Economy Strategy. This is a great opportunity to set reduction targets and potentials and make them binding. In order to reduce the use of primary raw materials and thus Germany's dependence on imports, as stipulated in the coalition agreement, the recycling potential of metallic raw materials must be exploited to a greater extent. However, this potential depends on the amount of scrap available in Germany and varies from metal to metal. The potential for increasing the use of recyclates is significantly higher for iron and steel than for copper and aluminium (see chapter *'Metal recycling potential'*).

It is important that policy measures go beyond targets for the use of secondary metals, as otherwise they will often not have the desired effect. Instead, they must aim to increase the availability of scrap of appropriate quality: For example, reusability, disassembly, and recycling should be facilitated and ensured in the design of products. In addition, digital product passports should be made mandatory for all products and used to inform recycling companies about the composition of products. This will help, for example, in identifying materials and processing alloy scrap.[xii][126]

The collection of end-of-life products also needs to be improved. This requires additional recycling capacity[xiii] and improved recycling technologies.[xiv] Scrap exports also need to be managed to ensure high quality recycling. For example, aluminium scrap produced in the EU is often exported due to a lack of sufficient recycling capacity in Germany or the EU. Imports of primary metals could be significantly reduced by using more of this scrap.[127]

2. Increased use of secondary metals

For recycling to be worthwhile, in addition to the availability of sufficient scrap of the right quality, there must be guidelines or financial incentives for companies to favour the use of secondary raw materials over primary raw materials. The introduction of a lower tax rate for recycled raw materials would be conceivable here. The introduction of a priority principle, whereby primary raw materials can only be used if secondary raw materials are not available on the market or in the industry, is also a possible measure.[128]

xii Aluminium, for example, is used in around 200 different alloys.

xiii Processing capacities for scrap in Germany are sometimes too low, for example for copper. In addition, some copper is lost to the steel scrap stream during the sorting process. Improved sorting is needed.

xiv The use and promotion of recycling technologies is essential, especially for high-performance materials that require precise alloy compositions.

3. Extending the useful life of goods (preventing premature wear and ensuring repairability)

Far too many products are replaced when their useful life could be significantly extended. There are many reasons for this: often the repair effort does not seem worthwhile, the fault is difficult for a layperson to identify, the product is difficult to open or disassemble. In some cases, this is due to planned obsolescence, i.e. premature wear and tear deliberately caused by product design. Policy measures must therefore include a ban on such planned obsolescence.

Since devices such as smartphones are often replaced because their software support expires or they are difficult to repair, manufacturers should be legally obliged to guarantee software updates and thus the safety and functionality of the devices for a much longer period of time. Researchers suggest extending this guarantee to seven years, for example.[129] To improve repairability, manuals and assembly information should also be made publicly available. To address the waste of raw materials and improve repairability, WWF also recommends extending manufacturers' responsibility for collecting and recycling equipment when it is no longer in use.[130]

The *Right to Repair*, agreed by the EU in February 2024 and to be transposed into national law by Member States in the coming months, is an important step towards saving resources. The new law will require manufacturers to repair a selection of common household appliances. It extends the legal guarantee for repaired goods by one year and gives consumers the right to borrow an appliance while their own is being repaired. Spare parts should also be available at reasonable prices and digital information platforms should be set up. Each Member State must also introduce at least one measure to encourage repairs, such as repair vouchers, repair courses, support for repair cafés, or a reduction in the VAT rate for repair services.[131]

However, the agreement has gaps in several areas, as criticised by the *Round Table Repair* and the *Right to Repair Europe* alliance: for example, its scope is limited to smartphones, tablets, washing machines, dishwashers, dryers, refrigerators, monitors, servers, and welding equipment – with vacuum cleaners to be added in the future. Implementation into national law needs to be improved. The agreement also states that *Design for Repair* should not be actively prevented, but does not explicitly require manufacturers to do so.[132]

4. Stopping the waste of raw materials

As part of the National Circular Economy Strategy and beyond, the BMUV should examine how large quantities of iron, aluminium, copper, and nickel can be reduced and, where appropriate, replaced in areas where they are used. In the case of aluminium, this applies in particular to the packaging industry, which accounts for 13 percent of the aluminium used in Germany. As aluminium is very difficult to recycle, it is often *'downcycled'* (see chapter *'Other potential savings'*). The BMUV should therefore consider both a beverage or food packaging tax – especially for beverage cans and coffee capsules – and also examine where bans could be applied. Bans should also be considered for disposable electronic products such as tobacco heaters or disposable e-cigarettes.

On average, smartphones are used in Germany for around two years. This period of use could be considerably extended. Photo: Elly Brian, Unsplash

Federal Ministry of Economics and Climate Protection (BMWK)

1. Preparing for and increasing recycling of new technologies

As various so-called future technologies, such as wind turbines and solar installations, are only occasionally reaching the end of their life cycle today and are not yet available in large quantities as scrap, there is currently hardly any recycling capacity in Germany and the EU. However, this situation is set to change dramatically in the coming years (see chapter *'Increasing recycling of new technologies'*), affecting not only the base metals iron, aluminium, copper, and nickel, but also many other raw materials such as rare earths, silver, and silicon. It is therefore very important that policies are put in place today to create the necessary collection infrastructure, strengthen recycling capacities, and promote the use of secondary raw materials in new technologies in the future. Here, as with other systems and products, product-specific minimum quotas for the use of secondary raw materials are conceivable measures.

2. Implementation of the *Critical Raw Materials Act*

The *Critical Raw Materials Act* obliges Member States to both *'moderate'* the demand for Critical Raw Materials and to expand the circular economy.[133] The BMWK should therefore examine measures that address the forecast growth in raw material consumption and identify reduction potential. The measures should be broken down by raw material. The Federal Statistical Office should publish annual figures on the use of Critical Raw Materials (broken down by RMC). In addition, the BMWK should report annually on the status of recycling of critical metals, possibly via DERA or BGR.[134] The resources of the Raw Materials Fund should also be mobilised to support the circular economy, and start-up financing or technology development should be supported.[135]

Federal Ministry of Health (BMG)

In the healthcare sector, the BMG should review the potential for metal savings and, in particular, address the problem of downcycling of metal devices. Various approaches are already in place to separately collect and recycle disposable metal cutlery. The University Hospital in Bonn has also started to recycle disposable surgical equipment, including staplers and ultrasonic scissors. Together with other non-infectious disposable devices (such as forceps, clamps, petri dishes, and anaesthesia equipment), these are sterilised in the hospital's microbiology department and then mechanically recycled. This means that about 80 percent of the material can be recycled.[136] Further research and support is needed. The BMG should investigate how the recycling of disposable metal cutlery can be expanded while ensuring the highest health and safety standards, and what alternatives exist to its use.

Political action, now!

In recent years, the security of raw material supply has increasingly become the focus of political attention. This is reflected in the EU's decisive action as well as the German Chancellor's trips to Indonesia, Argentina, and the African continent. However, instead of constantly seeking new sources of raw materials,

When renewable energy technologies reach the end of their lifespan, they must be recycled appropriately to prevent downcycling. Photo: adege, Pixabay

the focus should be on expanding the circular economy and actively exploiting the potential for reduction. After all, we will continue to need metals in all areas of our lives. In order to guarantee this comprehensive supply for people in societies in the Global South and for future generations worldwide, it is therefore urgently necessary to curb the use of primary raw materials in Germany and Europe and to end the unsustainable use of metallic raw materials. Many of the reduction potentials require clear political action. The urgent need to conserve resources can only be addressed by creating the right framework conditions.

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